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Study on influence of weather parameters on growth and development of insect population sunflower (*Helianthus annus*)

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Abstract
Sunflower is an important oilseed crop in India. Yield loss in sunflower is mainly due to moderate to severe insect pest incidence. In this ongoing study, an effort has been made to appraised the insect population dynamics and weather parameters influence on defoliator, leafhopper, thrips and capitulum borer. Different non-linear models were fitted to assess the insect population dynamics of sunflower. Based on R^2, Adjusted R^2 and Root Mean squared Error value, logistic, geometric and exponential models were observed to be best fitted for TH and CB whereas 6^{th}, 7^{th} and 8^{th} Degree Polynomial Regression models were employed when these above mentioned non-linear models were not appropriately fitted. For DF and LH 8^{th} degree polynomial regression models was found to be best fitted. For all the insects in sunflower, coefficient of maximum RH and maximum temperature were found to be significant at 5 per cent level of significance, whereas other abiotic factors may influence indirectly on these insects.

Keywords: Sunflower, weather parameters, multiple linear regression, non-linear models

Introduction
Sunflower (*Helianthus annuus* L.) was originated from North America (i.e., in the Fertile Crescent, Asia or Central America). The duration of cultivation was ranging from 125 to 130 days. More than fifty species of insect has been reported on sunflowers in the Indian subcontinent. Among them, majorly cutworms (*Agrotis spp.*), sucking pests, leaf, and planthoppers Thrips, whitefly (*Bemisia tabaci* Gennadius), defoliators (*Spilosoma.obliqua, Spodoptera litura,* and *Plusia orichalcea*.) and capitulum borer (*Helicoverpa armigera* Hubner) were of economic concern (Basappa, 2004) [1]. *H. armigera* was considered as the most serious pest since it will develop resistance to the application of insecticides greatly, have broad host range and they may persist in cropping area from year to year. They appear during late budding to till late seed fill stage. Thrips population will be abundant during hot, dry spring followed by mild dry winter. Their damage was most remarkable when the seedlings were not actively growing. Different seasons, cropping period and the agro-climatic zones had an impact on the insect pest damage intensity. They also influenced by fluctuations of the weather parameters and other biotic factors. Analysing the population dynamics of the insect pest in relation to meteorological parameter helps in taking preventive measures for the management of the pest. The information gathered from a specified area for the given period on pest population and climatic factor will be employed in building the insect-weather model for forecasting the future outbreaks. In this paper an attempt has been made to find the influence of weather parameters and to fit the appropriate models.

Materials and Methods
The database for this study was rooted on the experiment conducted by All India Coordinated Research Project on Sunflower (AICRP on Sunflower), ZARS, and Weather data was collected from Department of Agrometeorology GKVK, Bengaluru. The experiment was conducted under field condition in an area of 4.8m X 14.4m. The incidence of pest was recorded at weekly interval throughout the cropping period.
As study is verifiable in nature, in order to get knowledge of the structure of data, descriptive measures were computed. Correlation study was employed to know how the weather parameters were influencing on the insect infestation. To measure the intensity or degree of the linear relationship between two variables, Karl Pearson developed a formula called Correlation coefficient (r) and is defined as follows,

$$r(X,Y) = \frac{Cov\,(x,y)}{\sigma_x\,\sigma_y}$$

Where,
r = correlation coefficient between two variables.
Cov (x, y) = $\frac{1}{n}\sum(x_i - \bar{x})\sum(y_i - \bar{y})$

$$\sigma_x\,\sigma_y = \left[\frac{1}{n}\sum(x_i - \bar{x})^2 \,.\frac{1}{n}\sum(y_i - \bar{y})^2\right]^{1/2}$$

The significance of the correlation coefficient was tested using student t test and the formula is given below,

$$t = \frac{(\bar{x}-\mu)}{s/\sqrt{n}}$$

Where,
t = Student t statistic
$\bar{x}$ = Sample mean
μ = Population Mean
s = standard deviation
n = sample size

A regression model which involving more than one regressor variable is as called as multiple linear regression. The multiple linear regression model that described as follows,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + \varepsilon \qquad (1)$$

Where,
Y = dependent variable (Defoliator(DF), Leafhopper (LH), Thrips (TH), Capitulum borer (CB)).
x_i= independent variables(Weather parameters), i= 1, 2,…p
β_0= intercept of the regression equation.
β_1 …. β_p= are the regression coefficients.
ε = error term, which is assumed that the expected value of the error term in equation (1) is zero and has the constant variance σ^2.
The significance of the R^2 is tested by F-test.

Coefficient of determination (R^2)
Coefficient of determination (R^2)was used to assess the adequacy of the model, which was used to know the percentage contribution of the independent variable on the dependent variable. The quantity is as follows,

$$R^2 = \frac{SS_R}{SS_T}$$

Where,
SS_R = sum of squares due to regression
SS_T = Total sum of squares.

Test of significance of the R^2 was done by employing the F test and test statistic was defined as follows,

$$F = \frac{R^2/p}{(1-R^2)/(n-p-1)}$$

Where,
p= number of independent variables.
n = size of the sample.

The computed test statistic value of F was compared with the F table value at (p, n-p-1) degrees of freedom for the given level of significance.

Adjusted R^2 ($\bar{R}^2$)
It is a R^2 modification of that adjust for the number of explanatory terms in the model (p) relative to total number of data point (n). It is given as follows,

$$\bar{R}^2 = 1 - (1 - R^2)\frac{n-1}{n-p-1}$$

Where,
n -1 = degrees of freedom for population
n-p-1 = degrees of freedom for error

Root mean squared error
RMSE is the positive square root of the arithmetic mean of the squared error that is the difference between the observed value and fitted value.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}}$$

Where,
y_i = observed value
$\hat{y}_i$ = fitted value and
n = total no. of observations

Stepwise regression was one of the most regularly used algorithm used for variable selection. This method was an improvement over the forward selection and backward elimination. In this method, all the regressor variables entered into the model previously were reverified at each stage by using their partial F-statistics. The elimination of the variable from the model was done when the partial F- statistics value was less than the $F_{OUT.}$
Non-linear regression is a kind of regression analysis in which the model parameters and one or more independent variables are combined to form a non-linear function which was used for modelling purpose for observed data. The successive approximation method was employed for data set to build the models.
Exponential model, Modified exponential model, Sinusoidal model, Geometric model, Logistic model, 6th degree polynomial regression, 7th degree polynomial regression, 8th degree polynomial regression.

Result and Discussion
The calculation of descriptive statistics was conducted for Defoliator (DF), Leaf Hopper (LH), Thrips (TH) and Capitulum borer (CB), and outcomes were tabulated in the table 1.
The mean and variance value for the DF population was 0.227 and 0.19, with the average maximum and minimum occurrence of insect pest per SMW was 0.54 and 0.04 respectively. Skewness of data set was positive (1.049) and with platykurtic curve shape (2.214).
It was also has been observed that value of mean and variance for LH count data was 1.296 and 0.038, with the average presence of maximum and minimum number of insects per SMW was 1.58 and 0.96 respectively. The skewness value is 0.519 and the kurtosis value is -0.625.
It has been noticed that, TH population was positively skewed (0.509) with curve nature was estimated to be platykurtic (-

0.625). Average minimum and maximum pest occurrence per SMW was 0.01 and 0.84 respectively. Mean and variance for this data was 0.368 and 0.073 respectively.

However, for CB count data, 0.368 was estimated as mean and 0.70 as the variance, with 0.01 and 0.90 are the values of average maximum and minimum number of insect pest occurrence per SMW. The data set was positively skewed (1.599) with shape of the curve was mesokurtic (3.034) in nature.

In this study there was no significant relation between the DF population and weather parameters. Similarly, between LH population and the abiotic factors. And the association between TH population and weather parameters was non-significant. Hence, the DF, LH and TH were non significantly influenced by weather conditions. Kaneria *et al*. (2018) [4] Studied the seasonal incidence of pod borer (*Helicoverpa armigera*) on chickpea and outcome of the experiment was pod borer was highly negatively correlated with Maximum temperature and minimum temperature (r = -0.739) (r = -0.725). Wakil *et al*. (2010) carried out an investigation to know the influence of weather factors on tomato fruit worm (*Helicoverpa armigera*) in Punjab, there exists a positive correlation between temperature with larva population and fruit infestation, and shows a negative association between relative humidity with the larval population. Population of pod borers was significantly correlated with relative morning humidity (r = 0.695). A negative correlation was observed between CB and T_{MAX} (-0.724) at 5 per cent level of significance which conveys that CB count will reduce if the maximum temperature increases which is on par with the above sited review. Correlation between the sunflower insect pest and weather parameters were tabulated in Table 2. Nag *et al.* (2017) [4] stated that there exists the highest degree of association between diurnal variation and minimum temperature with YSB.

Table 3 shows the regression models were fitted by employing multiple linear regression analysis with step wise regression method of variable selection was used. Waiganjo *et al.* (2008) [6] studied the influence of weather parameters on thrips population in onion and step-wise regression study showed that minimum RH had a significance in the prediction of thrips population. The linear regression model for DF insect count data set was $\hat{y} = 0.564 - 0.053(Wind\ speed)$, this equation was not significant since the variable entered into the model was not significant. R^2, $\bar{R}^2$ and RMSE value for the model 0.360, 0.106 and 0.106 respectively. Similarly, the linear model for LH population was $\hat{y} = 0.396 - 0.035(Wind\ speed) + 0.018(MAX)$, wind speed and the maximum temperature were the variables entered into the model and both of them were non-significant. Respective R^2 $\bar{R}^2$ and RMSE values were 0.203, 0.165 and 0.167. The multiple linear regression model for TH population was $\hat{y} = -0.2017 + 0.053(MAX)$, MAX temperature was admitted into the model. The MAX temperature was found to be significant at 5 per cent significance level. The R^2, $\bar{R}^2$ and RMSE values for the model were 0.307, 0.109 and 0.21342 respectively. The regression model for CB population was $\hat{y} = 4.815 - 0.209(RH - 2)$, afternoon relative humidity factor was significant at 1 percent significance level. Respective R^2, $\bar{R}^2$ and RMSE values were 0.689, 0.600 and 0.248. Cammell and Knight (1992) [2] they also noticed that the distribution and abundance of a particular pest species will depend on the climatic changes.

Fitting of non-linear models for Sunflower pest population was carried out and the results were tabulated in Table 4 with parameter estimates and their significance. Firstly, for DF count data 6th 7th and 8th degree polynomial regression models were fitted. 8th degree polynomial regression (DPR) model was observed to be best fitted model when compared to other two models. R^2, $\bar{R}^2$ and RMSE value for this model was 0.839, 0.724 and 0.053 respectively. R^2 was significant at 5 per cent level of significance and 83.9 per cent of variability in the best-fitted model was explained by it. Similarly, for LH count data 6th 7th and 8th DPR models were fitted among which 8th DPR was best fit with R^2, $\bar{R}^2$and RMSE value was found to be 0.929, 0.894 and 0.049 respectively. R^2 was significant at 5 per cent level of significance with explaining variability of 92.9 per cent. For TH population modified geometric, sinusoidal and gaussian non-linear models were best. Among which modified geometric model was best model with R^2 value of 0.739 which was significant at 5 per cent significance level, $\bar{R}^2$ value of 0.608 and 73.9 per cent of variability was explanation. Respective RMSE value for this model was 0.131. Hubbell (1997) [3] made a geometric model of random variables for insects in apple orchard to manage the apple insect pest by applying insecticides. However, for CB data set logistic, geometric and exponential models were best. For this data set appropriate model was logistic model, R^2, $\bar{R}^2$ and RMSE value of this model was 0.937, 0.905 and 0.063 respectively. Significance of R^2 was 0bserved at 5 per cent level of significance which explains the variability of 93.7 per cent. The non-linear models for PD data point are modified exponential, exponential and geometric. Among which modified exponential was best fit with R^2, $\bar{R}^2$and RMSE value was 0.907, 0.880 and 0.020 respectively and R^2 was significant at 5 per cent significance level. 90.7 per cent of variability in the model was explained by R^2. Fig 1, 2, 3 and 4 represents the fitted non-linear models for Defoliator, Thrips, Leafhopper and Capitulum borer.

Table 1: Descriptive statistics on sunflower insect pest

Pest name	Descriptive Statistics					
	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
DF	0.04	0.54	0.227	0.019	1.049	2.214
LH	0.96	1.58	1.296	0.038	-0.502	-0.170
TH	0.01	0.84	0.368	0.073	0.519	-0.625
CB	0.01	0.90	0.275	0.070	1.599	3.304

Table 2: Correlation between DF, LH, TH, CB, PD and weather parameters.

Pest name	MIN	MAX	RH-1	RH-2	RF	SSH	WS
DF	0.315	0.311	0.194	-0.157	-0.600	-0.146	0.030
LH	0.293	0.237	0.019	0.077	-0.320	-0.201	0.182
TH	-0.033	0.389	0.011	-0.267	-0.217	0.308	0.175
CB	-0.543	-0.724*	0.143	0.107	0.332	-0.133	-0.069

* 5 per cent level of significance, ** 1 per cent level of significance

Table 3: Multiple linear regression model for Insects in sunflower population with different weather parameters.

Pest name	Intercept	WS	MAX	RH-2	R^2	Adjusted R^2	RMSE
DF	0.564*	-0.053 NS	-	-	0.360NS	0.177	0.106
LH	0.396NS	-0.035NS	0.018NS	-	0.203NS	0.305	0.165
TH	-0.207*	-	0.053*	-	0.307*	0.109	0.213
CB	4.815**	-	-	-0.209**	0.689*	0.600	0.248

* 5 per cent level of significance, ** 1 per cent level of significance, NS Non-significant

Table 4: Non-linear models for insect pests in sunflower

Pest name	Model name	Parameter estimates									R^2	Adjusted R^2	RMSE
		a	b	c	d	e	f	g	h	i			
DF	8th DPR	19.261 NS	-46.401 NS	43.002 NS	-20.275 NS	5.442*	-0.867 NS	0.081*	-0.0041*	0.0001*	0.839*	0.724	0.053
	7th DPR	7.276*	-16.357 NS	13.978 NS	-5.813*	1.304*	-0.161*	0.010*	-0.0003*	-	0.740*	0.658	0.067
	6th DPR	-0.356 NS	0.867*	-0.327 NS	0.036*	0.002*	-0.0007*	0.0003 NS	-	-	0.329 NS	0.097	0.108
LH	8th DPR	20.302 NS	-45.778 NS	41.749 NS	-19.291 NS	5.050*	-0.781*	0.071**	-0.0035*	0.00007*	0.929**	0.894	0.049
	7th DPR	10.612 NS	-21.487 NS	18.283 NS	-7.598 NS	1.705*	-0.211*	0.014**	-0.0004*	-	0.896*	0.792	0.059
	6th DPR	0.609*	1.091*	-0.468*	0.069*	-0.001*	-0.0004*	0.0001*	-	-	0.532 NS	0.387	0.126
TH	Modified geometric	0.0137NS	10.923**	-	-	-	-	-	-	-	0.739*	0.608	0.131
	Sinusoidal	0.389**	0.316*	0.749**	-3.011**	-	-	-	-	-	0.689 NS	0.440	0.143
	Gaussian	0.809**	3.888**	1.533**	-	-	-	-	-	-	0.649 NS	0.368	0.152
CB	Logistic	-0.129*	-2.908NS	0.093*	-	-	-	-	-	-	0.937*	0.905	0.063
	Geometric	0.051*	0.122**	-	-	-	-	-	-	-	0.909*	0.883	0.012
	Exponential	0.022NS	0.363**	-	-	-	-	-	-	-	0.898*	0.869	0.080

DPR = Degree Polynomial Regression, * 5 per cent level of significance, ** 1 per cent level of significance, NS Non-significant.

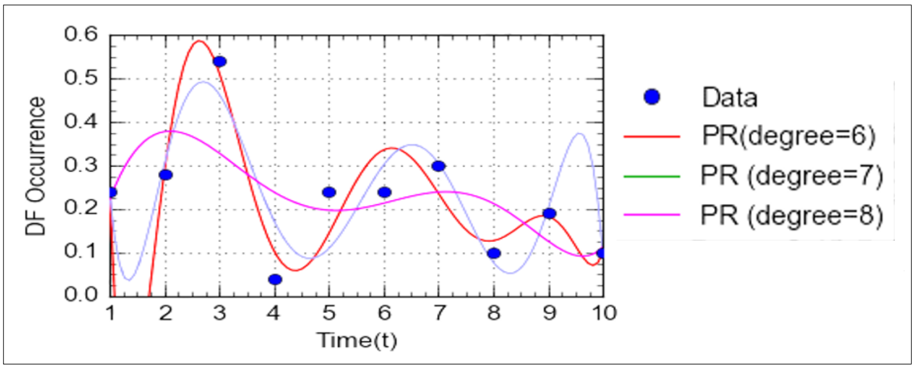

Fig 1: Non-linear models for DF population

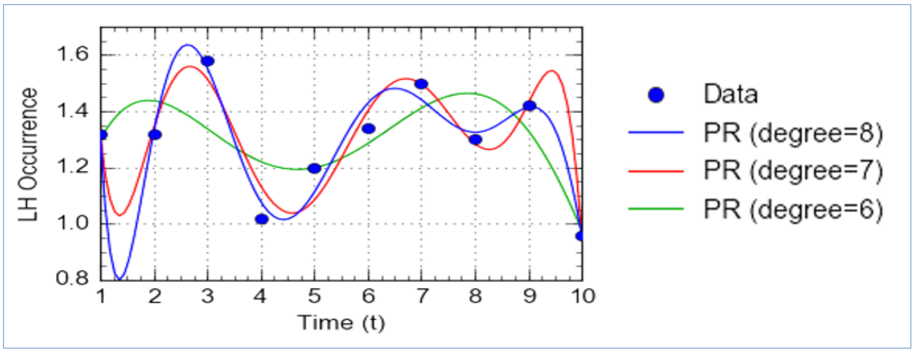

Fig 2: Non-linear models for LH population

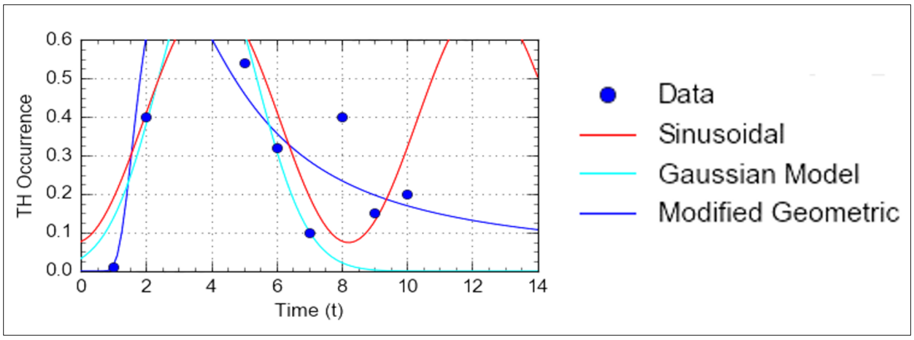

Fig 3: Non-linear models for TH population

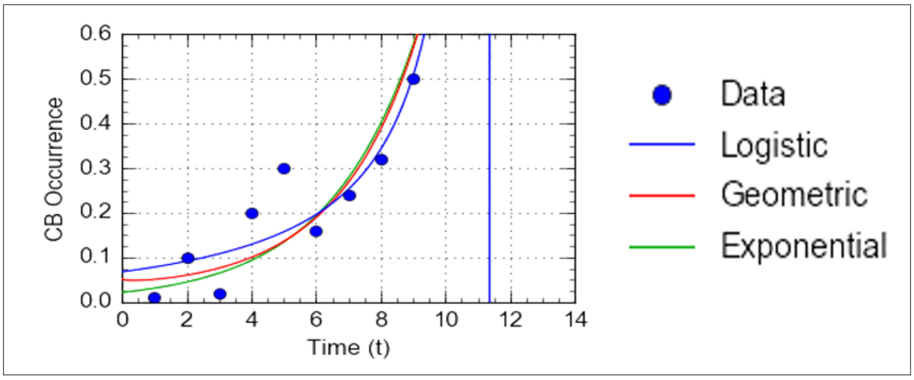

Fig 4: Non-linear models for CB population

Conclusion

A judicious attempt has been made in the present study to understand the influence of weather parameters such as wind speed, minimum and maximum temperature, afternoon relative humidity, sunshine hours on growth and development of sunflower insect pest *viz.*, Defoliator, Leafhopper, Thrips and Capitulum borer. Secondary data on insect pest of sunflower was collected from All India Coordinated Project (AICRP) on sunflower, UAS (B)-560065 and daily weather data was collected from Department of Agrometeorology, UAS, GKVK, Bengaluru-65. By employing multiple linear regression and based on the values of R^2 , Adjusted R^2 and Root mean squared error (RMSE) it can be concluded that the weather parameters such as maximum temperature and afternoon relative humidity were significantly influencing on sunflower insect pest. Since the value of R^2, Adjusted R^2 was high and RMSE value was less. As the data was not linearly distributed, non-linear models such as 6th, 7th, and 8th degree polynomial regression, modified geometric, geometric, guassian, sinusoidal, logistic and exponential models were fitted and their goodness of fit was measured by values of R^2, Adjusted R^2 and Root mean squared error (RMSE). And the best fitted models were 8th degree polynomial regression, logistic, exponential and geometric models.

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